Runoff-Streamflow lag time:

Lag time is defined as the time interval between the occurrence of runoff-producing rainfall and snowmelt over a watershed and the resulting discharge peak at the outlet of that watershed. A watershed's lag time is closely related to the length, slope, and roughness of the longest flow path as well as the size, shape, landcover, and soil properties of the watershed. Here we have determined the lag time from lag-correlation analysis between the daily total runoff and streamflow at each of the 22 hydrograph monitoring locations across 17 basins in Afghanistan.

The discharge regime in Afghanistan is strongly influenced by snowmelt, making the rivers perennial by nature. Therefore, we have considered January to July (212 days)—the most active part of the season—total runoff and discharge estimates in the lag-correlation analysis. The analysis includes 20 years (2001-2020) of data for each time series (runoff and discharge). A correlation coefficient (r^2) is calculated between the total runoff and streamflow time series by shifting forward streamflow time series by a day for 12 days. The analysis yields 12 correlation coefficient values between total runoff and streamflow where streamflow lagged total runoff by up to 12 days (0-11 days). Figure 1 shows an example of the correlation between total runoff and streamflow with lag of 0 to 11 days for the northern Kabul_Indus hydrograph monitoring point. Finally, the corresponding lag days for the top three correlation coefficient (r^2) values were identified as the representative lag day(s) between total runoff and streamflow. In this example, streamflow response lagged total runoff between 1 to 3 days. This implies that a peak in streamflow at this northern Kabul_Indus point is more likely to occur between 1 and 3 days after the occurrence of runoff producing events in the catchment area.

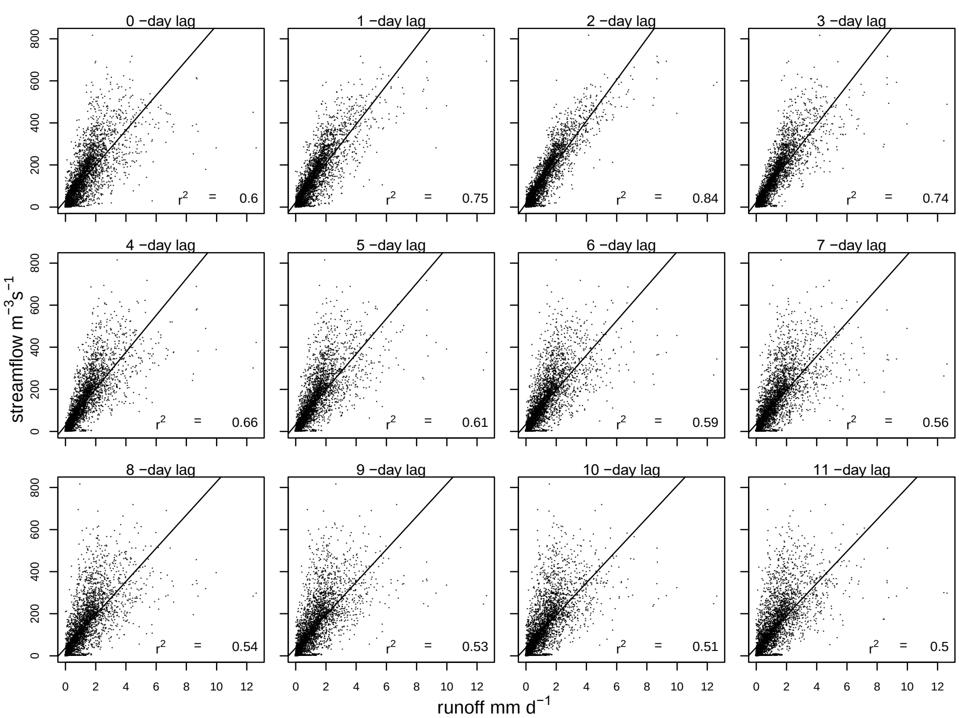

Figure 1: Relationship of streamflow to total runoff for each 0 to 11-day lag for the northern Kabul_Indus hydrograph monitoring point.

Streamflow and Runoff Hydrographs:

Streamflow: the streamflow hydrograph illustrates the amount and timing of runoff accumulation in the rivers and is needed to accurately assess the potential for flood conditions. Streamflow has been estimated by applying the Hydrological Modeling and Analysis Platform (HyMAP) version 2 river routing with existing FEWS NET Land Data Assimilation System (FLDAS) (McNally, 2017) parameterization of the Noah 3.6 land surface model (LSM) for Afghanistan in NASA's Land Information System (LIS) software framework. The Noah 3.6 land surface model and HyMAP 2 routing are run at 1-km spatial resolution and one-quarter hour temporal resolution using Global Data Assimilation System (GDAS) data as a primary forcing.

FLDAS uses a nine-year spin-up of the LSM to produce stable snow and soil conditions representing the climatological model state for 1 October. Using this 1 October LSM climatology state, a two-year spin-up of the HyMAP 2 routing scheme was performed to produce stable discharge conditions in the rivers of Afghanistan. Synchronizing with FLDAS LSM, a climatological state of river discharge for 1 October was produced. The Noah 3.6 LSM and HyMAP 2 models are run in tandem from 1 October, 2000, to present, producing daily outputs, and resetting the models' climatological states on 1 October of each year so that each hydrologic year begins with a consistent set of land surface and river discharge states.

Total Runoff: total runoff is the summation of water from rain, snowmelt, or other sources (e.g. potential glacier melt) that flows over the land (surface runoff) and that flows laterally from the unsaturated soil zone towards the streams (subsurface runoff). The total runoff comes from FLDAS Noah 3.6 LSM for central Asia. The model is a physically based approach which simulates important bio-geophysical, hydrological, and energy balance processes that occur at the surface.

Here we present the resulting datasets of runoff and streamflow in three charts, in comparison with mean, low, moderate, and extreme conditions from historical analysis. Hydrographs are generated at 22 locations, based on population density and major urban areas. The GDAS temperature data are also presented in a fourth chart. The charts are as follows:

a) Streamflow: the streamflow hydrograph presents current season streamflow in comparison with last season, median, low, high, and extreme streamflow at the selected point. Median streamflow is calculated from the daily streamflow timeseries for the period October 2000 to September 2020 (20 years). Similarly, the low, high, and extreme streamflow represent the 25^{th}, 75^{th}, and 95^{th} percentile value of the streamflow with respect to the same October 2000 to September 2020 time period. On the streamflow hydrograph, the red and yellow horizontal lines mark the estimated 3-year return period discharge and 75% of the 3-year return period discharge values respectively. The 3-year return period discharge can be considered the bankfull discharge at the selected point, and bankfull is when a river is full to its capacity at a specific point. Therefore, bankfull illustrates the amount of discharge that is needed to assess potential flood conditions. In absence of in-situ discharge data, the bankfull discharge at these specific points has been computed through flow frequency analysis of the estimated discharge for the period of October 2000 to September 2020. By fitting a log Pearson II and Gumbel curves in the distribution of the annual maximum discharge, the equivalent discharge magnitude of 3-year return period is determined as the bankfull discharge.

b) Catchment Runoff: the runoff chart shows the progression of current season total runoff with respect to last year and median runoff over the catchment area of the points for which streamflow hydrographs are presented.

c) Streamflow and Runoff: the streamflow-runoff chart shows both streamflow and catchment runoff together with two different Y-axes. The Y-axis on the left represents streamflow, and the Y-axis on the right represents runoff. The shaded areas on the chart denote 25th, 75th, and 95th percentiles of the streamflow representing low, high, and extreme flow ranges, respectively. The percentile and the median (solid black line) values are for streamflow with respect to October 2000 to September 2020. The theoretical 3-year return period discharge value as bankfull discharge information is also marked on this chart with red and yellow lines where red line denotes bankfull discharge value, and the yellow line denotes 75% of the bankfull discharge value. The prime objective of this combined streamflow and runoff chart is to track the streamflow response to runoff. Typically, streamflow responds to runoff with a certain lag time depending on the size, shape, and other properties of the catchment. Using lag correlation analysis, runoff to streamflow lag time has been calculated and marked on the upper left corner of this combined chart. This is helpful in determining expected streamflow characteristics depending on the current runoff conditions.

d) Temperature: the temperature chart shows the daily progression of the current season basin-averaged GDAS near-surface air temperature in comparison with last season, average, and the range of near surface air temperatures for the October 2000 to September 2020 period. In the case of multiple hydrography monitoring points within one basin, the same basin's temperature chart is shown with streamflow and runoff for all the hydrography monitoring points within the basin.

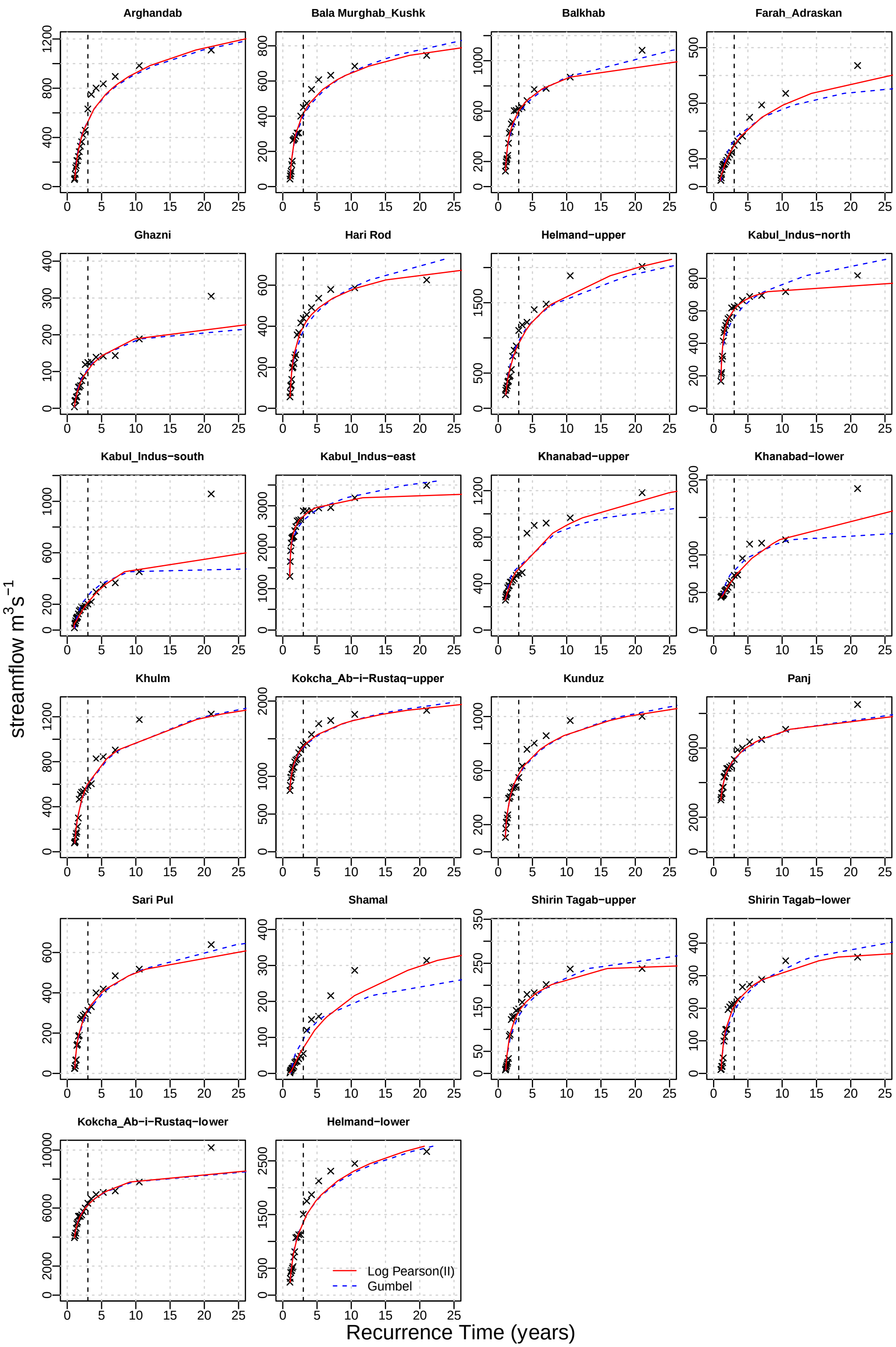

Figure 2: Frequency analysis curves of estimated annual maximum discharge fitted with log Pearson II and Gumbel theoretical curves.

McNally, A., Arsenault, K., Kumar, S., Shukla, S., Peterson, P., Wang, S., Funk, C., Peters-Lidard, C., Verdin, J. (2017). "A land data assimilation system for sub-Saharan Africa food and water security applications." Scientific Data 4: 170012.